

RECENT DEVELOPMENTS IN RESEARCH ON SHOT-HOLE BORER CONTROL

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In a series of 12 field experiments, 26 insecticides, two fungicides and two insect pathogens were evaluated for shot-hole borer control. The two fungicides, Bordeaux Mixture and nickel chloride were found to be ineffective. The fungus *Beauveria bassiana* and the bacterium *Bacillus thuringiensis* did not show any adverse effects on shot-hole borer build up. Of the insecticides tested, only heptachlor at the rate of 1.7 to 2.3 lb ai (active ingredient) per acre gave sufficient borer control comparable to that obtained from 1.5 lb ai dieldrin per acre. A single application of heptachlor at these rates was found to be very effective up to a period of 15 months. Two organophosphate insecticides, fenitrothion and fenthion were effective only for a maximum period of two months with a single application of 2.5 lb ai per acre. It was generally clear that only insecticides of the organochlorine type possess the required degree of efficiency and persistence in controlling Shot-hole Borer. The insecticide endrin was evaluated in one experiment, and gave results as good as those obtained with heptachlor. This compound needs further investigation for controlling shot-hole borer. The tortrix side effect of heptachlor was less than that of aldrin or dieldrin and it appears, therefore, that heptachlor is at present the most suitable insecticide to control Shot-hole Borer.

Since the withdrawal of the recommendations for the control of Shot-hole Borer (*Xyleborus fornicatus* Eichh.) with dieldrin in 1966 (see Cranham 1961; Danthanarayana 1966), investigations on controlling this pest were intensified, with the object of finding a more acceptable method of control. Both laboratory and field experiments were conducted to seek biological methods and suitable insecticides to control the beetle itself, and also, to look into the possibility of using fungicides to control the ambrosia fungus (*Monacrosporium ambrosium*) on which the beetle feeds. This paper presents the results of 12 field experiments on shot-hole borer control. The conclusions based on these results led to the amended recommendations given to estates for shot-hole borer control. These recommendations are given in a subsequent paper (Danthanarayana 1968).

Materials and methods

The location of the experiments are given below : E19—St Coombs, Talawakele; E28, E43—Goorookoya, Nawalapitiya; E32, E41—Deltotte, Galaha; E33—Carolina, Watawala; E34, E35—Balangoda, Bogawantalawa; E 42—Downside, Welimada; E44—Rothschild, Pussellawa; E45—Moolgama, Panwiltanne, and E46—Anningkande, Deniyaya. All experiments were of the randomized block design; with four replicates in experiments E19, E28, E32, E41, E42, E43, E44, E45 and E46; five replicates in E33 and E34, and seven replicates in E35. These experiments were carried out in pruned seedling tea or in new clearings of clonal tea, from 1965 to 1968. All experiments except E19 had a standard plot size of 1/20 acre. In addition to the chemical and other treatments, an untreated control was included in each experiment. The treatments are listed in Tables 1 to 12.

Three types of insecticides, namely organophosphate, carbamate and organochlorine, were evaluated in these experiments. The application of organophosphate and carbamate insecticides with low mammalian toxicity was done with mist-blowers, with a spray volume of 40 gallons of water per acre. The organochlorine insecticides and others with high mammalian toxicity were applied with hand-operated knapsack sprayers having nozzles with disc size 1.6 mm, with a spray volume

of 80 gallons of water per acre. In both types of spraying, the spray was well directed onto the bush frames from all sides so as to obtain a good cover. In experiment E28, the spraying was carried out immediately after pruning, but in all others the spraying was done between tipping time and end of one year after pruning.

The efficacy of different treatments was normally evaluated at bi-monthly intervals, by taking 25 or 50 sample units per plot. Each sample unit was a piece of tea stem four inches long and 3/8 inch in diameter (Judenko 1958). These samples were dissected in the laboratory to determine the numbers of all live stages (eggs, larvae, pupae and adults) of the beetle and the number of galleries present. As the number of occupied galleries indicate the degree of current damage, this has been taken as the criterion for damage evaluation. The data collected were subjected to analysis of variance on $\log(n+1)$ or $\sqrt{n+1}$ transformed values.

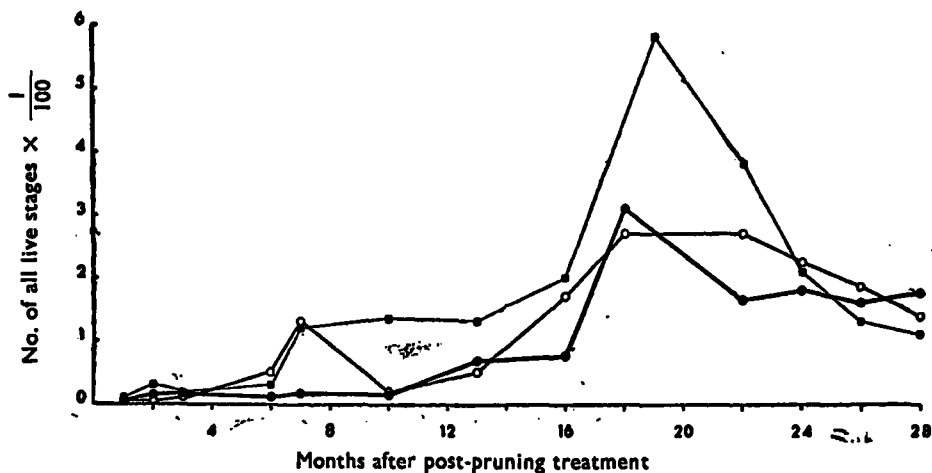


FIGURE 1 — Comparison of the degree of shot-hole borer control obtained with 1.5 lb dieldrin and 2.3 lb heptachlor per acre.

- — Heptachlor
- — Dieldrin
- — Untreated control

Experiments & Results

A—Evaluation of insecticides

Experiment E32

In this experiment, the insecticides chlorfenvinphos (Birlane 24% EC), arpo-carb (Unden 20% EC), dichlorvos (Nogos 50 EC), fentitrothion (Sumithion 50% EC), SD-3562 (Bidrin 85%) and the fungicide nickel chloride were compared with the untreated control. Nickel chloride was sprayed at fortnightly intervals at the rate of 3.75 lb nickel chloride per acre per application. Altogether there were seven treatments including the untreated control. The rates of application are given in Table 1. The sampling was carried out twice, at two and four months after treatment. The experiment was concluded at this stage because none of the treatments were found to be effective. The results presented in Table 1 indicate that the fentitrothion treatment showed a slight reduction of shot-hole borer numbers at two months after treatment, but this did not persist up to four months.

TABLE 1—Post-treatment counts of all live stages of Shot-hole Borer in Experiment E32

Treatment	Dose (lb ai per acre)	No. per 200 sample units (months after treatment)		Mean No. per 50 units (as $\sqrt{n+1}$)
		(2)	(4)	
Chlorfenvinphos	3.3	114	210	5.85
Arpocarb	1.6	260	184	6.65
Dichlorvos	3.7	163	130	5.31
Fenitrothion	2.5	90	125	4.25
Bidrin	1.1	383	138	7.12
Nickel chloride	3.8	108	161	5.58
Untreated control		155	149	5.35
LSD at $P = 0.05$				1.34

NB—None of the treatments are significantly different from the untreated control

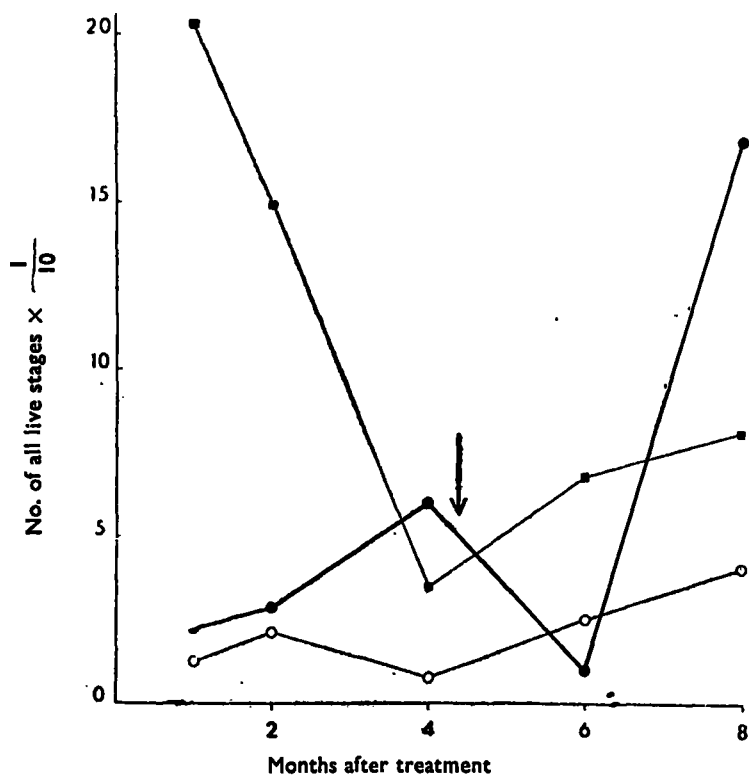


FIGURE 2— Comparison of the degree of shot-hole borer control obtained with a single application of heptachlor and two bi-monthly applications of fenitrothion (Sumithion)— The arrow indicates the time of the second application of fenitrothion.

- — 1.7 lb heptachlor
- — 2.7 lb fenitrothion per application
- — Untreated control

Experiment E41

The insecticides tested in this experiment were : methiocarb (Mesuro 75 % WP), dichlorvos, fenitrothion and heptachlor. The soil fumigant ethylene dibromide (Dowfume 85) and nickel chloride were also included as treatments. Ethylene dibromide emulsion is known to be effective against the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.), and a solution of this compound according to the formula of Gibson (1967) was used. Dichlorvos was applied in combination with a new resin sticker known as Estab (Velsicol International Corporation), at the rate of 10 pints per acre. Fenitrothion was sprayed twice with an interval of three months between spraying. As in the previous experiment, nickel chloride was sprayed fortnightly at the rate of 3.75 lb per acre per application. Altogether there were seven treatments including the untreated control. The rate of application and the results obtained are given in Table 2 and Figure 2.

TABLE 2—*Post-treatment counts of all live stages of Shot-hole Borer in Experiment E41*

Treatment	Dose (lb ai per acre)	No. per 200 sample units (months after treatment)					Mean No. per 50 units (as $\sqrt{n+1}$)
		(1)	(2)	(4)	(6)	(8)	
Methiocarb	1.0	24	101	93	132	109	4.30
Ethylene dibromide	1.2	135	104	42	28	58	3.95
Dichlorvos	4.0	114	70	66	47	134	3.87
Fenitrothion	2.5	22	28	60	10	167	2.58*
Heptachlor	1.7	16	23	8	25	40	2.11*
Nickel chloride	3.7	104	84	65	65	69	4.21
Untreated control		202	149	34	67	80	4.42
LSD at $P = 0.05$							1.29

* Significantly different from the untreated at $P < 0.05$

Heptachlor at the rate of 1.7 lb ai (6 pints 23% EC), and two applications of 2.5 lb ai fenitrothion (4 pints Sumithion 50% EC) gave significant reductions of the beetle population when compared with the untreated. The results (Table 2) show that the two applications of fenitrothion were effective up to a period of six months.

Heptachlor was consistently superior throughout the period of sampling. The carbamate insecticide, methiocarb showed some initial efficacy which was restricted to the first sample taken two months after its application.

Experiment E42

The insecticides included in this experiment were : azinphos-methyl (Gusathion 20% EC), heptachlor (23% EC), methiocarb (75% WP), fenthion (Lebaycid 50% EC), endrin (20% EC) and DDT (18% EC). In addition to these Bordeaux Mixture was included as a fungicide against the ambrosia fungus. Bordeaux Mixture was also used in combination with azinphos-methyl as one treatment. It must be noted that azinphos-methyl and Bordeaux Mixture are not compatible, but this combination was used because Venkataramaiah and Sekhar (1964) have found it to be somewhat effective against the coffee Shot-hole Borer (*Xylosandrus compactus* Eichh.). Altogether there were ten treatments including the untreated control. The results, at the end of 16 months after treatment are presented in Table 3 and show that 1.25 lb endrin (5 pints 20% EC) and 1.7 lb heptachlor gave significant reduction in shot-hole borer numbers. None of the other treatments were particularly effective. Azinphos-methyl and DDT treatments gave good results up to eight months after spraying. There was no significant difference between the efficacy of endrin and that of heptachlor.

TABLE 3—*Post-treatment counts of all live stages of Shot-hole Borer in Experiment E42*

Treatment	Dose (lb ai per acre)	No. per 200 sample units (months after treatment)								Mean No. per 50 units (as log (n+1))
		(2)	(4)	(6)	(8)	(10)	(12)	(14)	(16)	
Azinphos-methyl	1.0	1	8	50	34	181	82	84	202	0.84
Bordeaux Mixture	7.5	12	9	126	120	171	77	127	144	0.96
Azinphos-methyl + Bordeaux Mixture	1.0 + 7.5	18	2	26	121	148	120	151	215	1.01
Heptachlor	1.7	0	0	16	10	33	23	73	89	0.40*
Methiocarb	1.9	1	23	84	104	94	104	133	143	0.89
Ethylene dibromide	1.2	0	0	56	120	176	78	89	124	0.93
Fenthion	1.5	1	17	46	113	44	199	130	17	0.93
Endrin	1.2	0	7	1	36	48	3	21	38	0.39*
DDT	2.7	0	1	53	9	101	108	135	127	0.78
Untreated control		1	19	44	113	128	142	85	118	0.90
LSD at $P = 0.05$										0.24

* Significantly different from the untreated at $P < 0.05$

Experiment E43

In this experiment, fenitrothion, fenthion and methiocarb which showed some promise in the previous experiments were examined alone or in combination. Four new insecticides were also evaluated. These were : bromophos-ethyl (Nexagon EC 80), bromophos-methyl (Nexion EC 40), S-6538 (25% EC) and S-6607 (25% WP). The last two insecticides were phosphoric acid ester compounds supplied by Messrs Sandoz, Switzerland. In all, there were ten treatments including the untreated control. The plots were sampled on three occasions during a period of ten months. The results presented in Table 4 show that none of the treatments gave significant reductions in shot-hole borer numbers.

TABLE 4—Post-treatment counts of all live stages of Shot-hole Borer in Experiment E43

Treatment	Dose (lb ai per acre)	No. per 200 sample units (months after treatments)			Mean No. per 50 unit as (log (n+1))
		(4)	(7)	(10)	
Methiocarb	1.0	196	139	176	1.55
Bromophos-ethyl	1.5	186	155	334	1.70
S-6607	1.0	103	171	214	1.55
Fenthion	1.0	96	133	235	1.42
Fenthion+	1.0+				
Methiocarb	1.0	74	118	120	1.30
Fenitrothion	1.2	159	72	198	1.28
Fenitrothion+	1.2+				
Methiocarb	1.0	116	187	180	1.52
Bromophos-methyl	1.5	209	186	207	1.53
S-6538	0.6	72	103	167	1.25
Untreated control		109	133	150	1.41
LSD at $P = 0.05$					0.33

NB—None of the treatments were significantly different from the untreated control.

Experiment E44

In this experiment, more new insecticides were evaluated, together with higher doses of some of the insecticides from previous experiments. The new insecticides included were SD-9129 (Azodrin 50% EC), SD 8447 (Gardona 50% WP) and chlorfenvinphos (Sapecron 50% EC). The fungus *Beauveria bassiana* which is pathogenic to Shot-hole Borer was included as one treatment. Altogether there were 12 treatments including the untreated control. The fungus *B. bassiana* was included because in preliminary laboratory investigations, this fungus gave nearly 100% kill of Shot-hole Borer (Danthanarayana 1967). The strain of *B. bassiana* used in these experiments was obtained from the Institute of Entomology, Czechoslovak Academy of Sciences, Prague. The fungus was mass cultured in the laboratory in a liquid medium supplemented with ground shot-hole borer tissues. Prior to spraying, the fungus culture was homogenized. The resulting suspension was sprayed at the rate of 4 kg per acre in 80 gallons of water into which 2 ml of the wetting agent Teepol was added. The statistical analysis of the results (Table 5) showed that only fenthion at the rate of 2.5 lb (4 pints Lebaycid 50% EC) gave significant reductions in shot-hole borer numbers when compared with the untreated control. The data in Table 5 indicate, however, that the efficacy of fenthion was restricted to the first three months after treatment.

TABLE 5—Post-treatment counts of all live stages of Shot-hole Borer in Experiment E44

Treatment	Dose (lb ai per acre)	No. per 100 sample units (months after treatment)			Mean No. per 25 units (as log (n+1))
		(1)	(3)	(6)	
Azodrin	2.5	137	138	135	1.38
Gardona	1.2	38	148	270	1.38
Sapcorn	2.5	12	116	82	1.06
Bromophos-ethyl	2.0	29	76	230	1.07
Bromophos-methyl	2.0	100	136	165	1.38
Fenitrothion ('Sumithion')	2.5	32	60	55	0.97
Fenitrothion ('Folithion')	2.5	38	151	158	1.18
Methiocarb	2.8	52	210	136	1.36
Fenthion	2.5	25	36	124	0.70*
Azinphos-methyl	1.0	51	61	199	1.11
<i>Beauveria bassiana</i>		32	116	114	1.21
Untreated control		43	92	126	1.24
LSD at $P = 0.05$					0.41

* Significantly different from the untreated at $P < 0.05$

Experiment E45

In this experiment, three levels each of fenthion, fenitrothion and methiocarb which were fairly successful in controlling Shot-hole Borer in previous experiments were compared with 1.7 lb heptachlor. The insecticide S-6538 (25% EC) was included as a additional treatment. There were 12 treatments including the untreated control. The results presented in Table 6 show that only heptachlor gave consistently lower counts of Shot-hole Borer and that only this treatment was found to be significantly different from the untreated control at the end of ten months after spraying.

TABLE 6—Post-treatment counts of all live stages of Shot-hole Borer in Experiment E45

Treatment	Dose (lb ai per acre)	No. per 200 sample units (months after treatment)					Mean No. per 50 units (as log (n+1))
		(4)	(6)	(8)	(10)	(12)	
Methiocarb	1.0	402	428	86	34	75	1.51
Methiocarb	2.0	467	502	241	20	68	1.62
Methiocarb	4.0	573	578	207	62	118	1.78
Fenitrothion	0.6	263	448	163	90	119	1.64
Fenitrothion	1.2	379	480	109	33	52	1.55
Fenitrothion	2.4	262	576	216	65	103	1.68
Fenthion	0.6	405	448	189	64	135	1.66
Fenthion	1.2	491	594	260	62	109	1.76
Fenthion	2.4	480	537	240	53	107	1.75
S-6538	0.6	498	529	313	65	113	1.78
Heptachlor	1.7	251	184	83	11	58	1.20*
Untreated control		525	418	104	47	29	1.59
LSD at $P = 0.05$							0.18

* Significantly different from the untreated at $P < 0.05$

Experiment E46

The insecticides evaluated in this experiment were phosalone (Zolone 35% EC), vamidothion (Kilval 40% EC), heptachlor, chlordane (Intox-8), dicrotophos (Carbicon 50% EC), phosphamidon (Dimecron 50% EC), dimethoate (Roxion 40% EC)

and demeton-methyl (Metasystox R 20% EC). The microbial insecticide *Bacillus thuringiensis* (5% WP) was also included as a treatment. The heptachlor treatment was given in three ways, viz as a normal spray; in combination with 'Estab' (10 pints per acre,) and on treated absorbant paper. The purpose of the absorbant-paper treatment was to overcome the difficulties of obtaining mid-cycle spray coverage especially in the low country. Altogether there were 12 treatments including the untreated control. The rates of heptachlor application and the results obtained are presented in Table 7. All three types of applications and the chlordane application gave significant reductions in shot-hole borer numbers, when compared with the untreated. Comparisons by taking only the mean numbers of live individuals (Table 7), indicate that the heptachlor-Estab combination gave the best results followed by heptachlor alone, then by heptachlor-treated paper, and chlordane respectively. It must be noted that the quantity of chlordane used in this experiment was fairly high. Another noteworthy factor, was that the heptachlor-treated paper deteriorated with time as a result of weathering, but the results have been fairly satisfactory in spite of this shortcoming.

TABLE 7—Post-treatment counts of all live stages of Shot-hole borer in Experiment E46

Treatment	Dose (lb ai per acre)	No. per 200 sample units (months after treatment)				Mean No. per 50 units (as log (n+1))
		(3)	(5)	(7)	(9)	
Phosalone	0.4	133	135	94	34	1.32
Vamidothion	0.4	182	98	140	54	1.41
Heptachlor	2.3	95	78	47	14	1.03*
Heptachlor + Estab	2.3	40	60	54	31	0.97*
Heptachlor paper	2.3	72	52	83	32	1.09*
Dicrotophos	0.5	143	79	76	43	1.24
Phosphamidon	1.1	153	94	63	40	1.22
Dimethoate	0.9	132	112	64	27	1.20
Demeton-methyl	0.6	121	113	59	39	1.25
Chlordane	2.8	114	95	35	24	1.10*
<i>Bacillus thuringiensis</i>	2.0	229	91	95	47	1.38
Untreated control		154	89	105	44	1.32
LSD at $P = 0.05$						0.19

* Significantly different from the untreated at $P < 0.05$

B—Evaluation of heptachlor

Experiment E28

In this experiment, two levels of heptachlor were compared with one of dieldrin and the untreated control. The spraying was done immediately after pruning and the experiment was concluded after 28 months. The results are presented in Table 8. All treated plots gave significantly lower numbers of Shot-hole Borer than the untreated control. Dieldrin at the rate of 1.5 lb (6 pints 20% EC) and heptachlor at the rate of 2.3 lb (8 pints 23 % EC) per acre gave control superior to heptachlor at 1.2 lb (4 pints 23% EC). There was no significant difference between dieldrin and the high dose of heptachlor. All insecticides showed no variation in their efficacy at different dates of sampling. The results of this experiment are also illustrated in Figure 1 in which the types of control that are obtained with dieldrin and heptachlor are indicated.

Experiment E33

In this experiment, two annual applications of heptachlor at two levels were compared with dieldrin at two levels and aldrin. The data were analysed at the end of the first year after treatment and the results presented in Table 9 and Figures

TABLE 8—Post-treatment counts of all live stages of Shot-hole Borer in Experiment E28

Treatment	Dose (lb ai per acre)	No. per 200 sample units (months after treatment)													Mean No. per 50 ² units
		(1)	(2)	(3)	(6)	(7)	(10)	(13)	(16)	(19)	(22)	(24)	(26)	(28)	(as $\sqrt{n+1}$)
Dieldrin	1.5	3	6	15	6	17	14	65	73	308	163	176	157	170	2.96*
Heptachlor	2.3	2	1	8	44	130	19	51	171	270	276	219	191	140	3.57*
Heptachlor	1.2	4	15	20	33	54	30	81	249	419	266	228	164	167	4.00*
Untreated control		7	24	14	30	121	134	130	200	578	378	208	131	107	4.80
LSD at $P = 0.05$															0.78

* Significantly different from the untreated at $P < 0.05$

NB—Analysis of variance carried out on data up to 22nd month only

3 & 4. The results up to this time showed that all treated plots gave significantly lower numbers of Shot-hole Borer than the untreated plots. Heptachlor at 1.7 lb (6 pints 23% EC), and dieldrin at 1.5 lb (6 pints 20% EC) gave the best results; there was, however, no significant difference between their efficacy. Aldrin at 1.5 lb (6 pints 20% EC) was the next best followed by dieldrin at 0.5 lb and heptachlor at 0.6 lb per acre. All treatments showed no variation in their efficacy at different dates of sampling.

The second round of heptachlor was applied at the end of one year from the first, in order to restrict the population build up indicated in the sample taken at the 12th month (Table 9). The sequence of the population change after the second heptachlor application are given in Table 10. The results of different treatments throughout the entire period of the experiment are illustrated in Figure 3. It is clear from these results that annual applications of 1.7 lb (6 pints 23% EC) of heptachlor per acre give shot-hole borer control superior to that obtainable with a single application of aldrin or dieldrin at a similar dose.

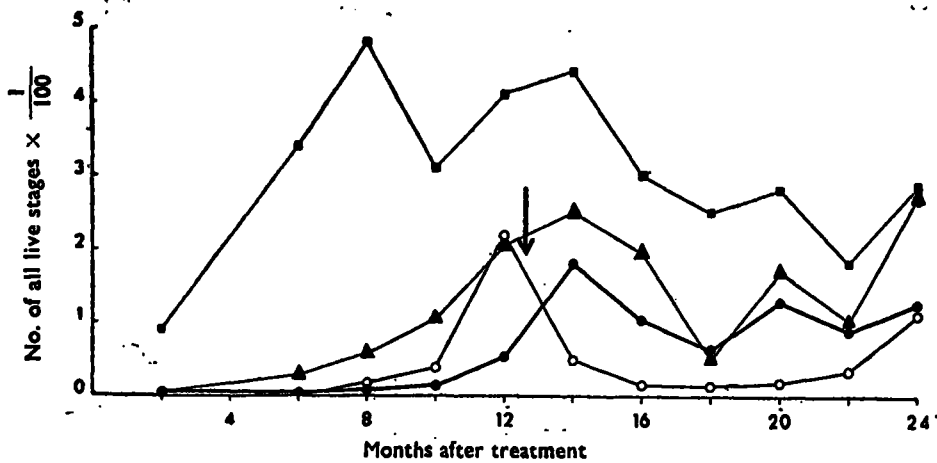


FIGURE 3—Comparison of the degree of shot-hole borer control obtained in young VP tea with single applications of dieldrin and aldrin, and two applications of heptachlor at an interval of one year — Arrow indicates the time of the second application of heptachlor

- — 1.5 lb dieldrin
- — 1.7 lb heptachlor
- ▲ — 1.5 lb aldrin
- — Untreated control

TABLE 9—Post-treatment counts of all live stages of Shot-hole Borer in Experiment E33 in the first year

Treatment	Dose (lb ai per acre)	No. per 125 sample units (months after treatment)					Mean No. per 25 units (as $\sqrt{n+1}$)
		(2)	(6)	(8)	(10)	(12)	
Heptachlor	0.6	26	64	116	192	300	4.9*
Heptachlor	1.7	4	1	17	41	225	2.7*
Dieldrin	0.5	20	20	114	232	381	5.4*
Dieldrin	1.5	1	5	9	13	54	2.5*
Aldrin	1.5	6	30	51	104	201	2.9*
Untreated control		92	342	478	308	407	7.9
LSD at $P = 0.05$							0.88

* Significantly different from the untreated at $P < 0.05$

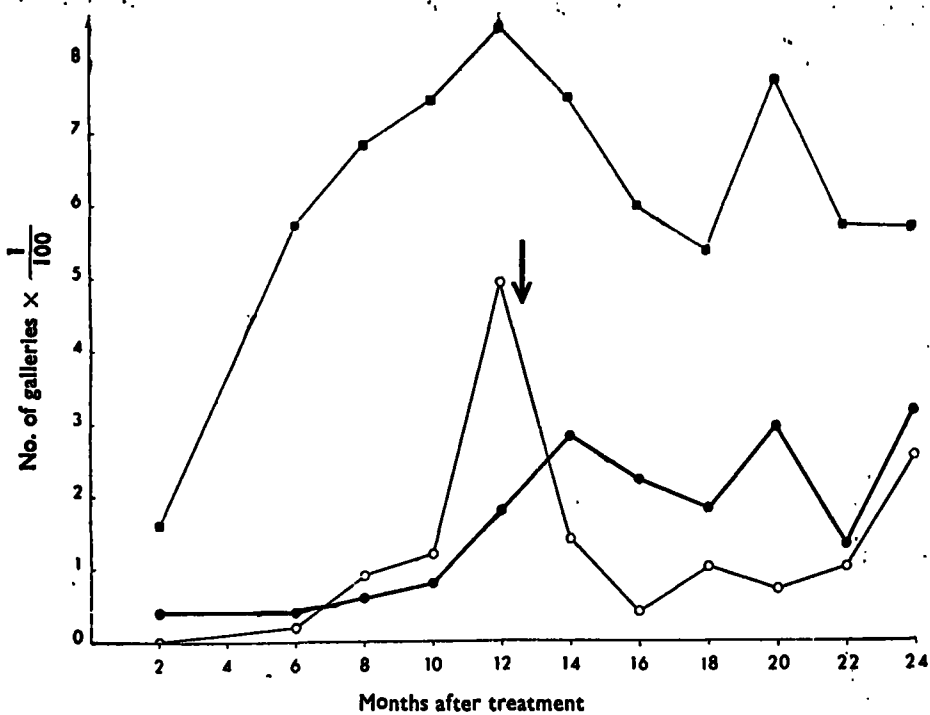


FIGURE 4— Comparison of the damage caused by Shot-hole Borer in young VP tea treated with a single application of dieldrin and two annual applications of heptachlor — The arrows indicates the time of the second application of heptachlor

- — 1.5 lb dieldrin
- — 1.7 lb heptachlor
- — Untreated control

TABLE 10—Post-treatment counts of all live stages of shot-hole Borer in Experiment E33 in the second year

Treatment	Dose (lb ai per acre)	No. per 125 sample units (months after treatment)						
		(14)	(16)	(18)	(20)	(22)	(24)	(26)
Heptachlor*	0.6	178	197	50	114	147	172	199
Heptachlor*	1.7	54	18	16	23	35	114	70
Dieldrin	0.5	384	295	197	284	95	209	257
Dieldrin	1.5	183	104	65	130	87	123	217
Aldrin	1.5	251	194	56	167	94	281	198
Untreated control		438	301	250	278	182	282	327

* Heptachlor treatments repeated at 13 months from the time of first application

Experiment E34

In this experiment, two doses of heptachlor were compared with two doses of dieldrin and one of aldrin. The rates of application of insecticides and the results obtained are given in Table 11. The lower doses of dieldrin and heptachlor were repeated at the end of one year after the first spraying. The experiment was concluded at the end of 19 months after treatment. Although the results for the entire

TABLE 11—*Post-treatment counts of all live stages of Shot-hole Borer in Experiment E34*

Treatment	Dose (lb ai per acre)	No. per 125 sample units (months after treatment)								Mean No. per 25 units (as $\sqrt{n+1}$)
		(5)	(7)	(9)	(11)	(13)	(15)	(17)	(19)	
Heptachlor†	0.6	46	55	73	273	458	356	289	159	5.2
Heptachlor	1.7	11	10	21	69	727	365	384	183	4.0*
Dieldrin†	0.5	48	35	129	233	356	256	227	116	5.0
Dieldrin	1.5	2	9	32	62	404	209	257	195	3.3*
Aldrin	1.5	4	86	23	37	600	325	309	288	4.1*
Untreated control		65	134	136	351	783	359	314	134	6.6
LSD at $P = 0.05$										2.4

* Significantly different from the untreated control at $P < 0.05$

† These treatments were repeated at 12 months after the first application

NB—Analysis of variance carried out on data up to 13 months

TABLE 12—*Post-treatment counts of all live stages of Shot-hole Borer in Experiment E35*

Treatment	Dose (lb ai per acre)	No. per 175 sample units (months after treatment)								Mean No. per 25 units (as $\sqrt{n+1}$)
		(5)	(7)	(9)	(11)	(13)	(15)	(17)	(19)	
Heptachlor	0.6	14	10	108	93	559	238	244	291	3.7
Heptachlor	1.2	17	28	23	39	403	236	202	237	2.8*
Heptachlor	1.7	29	20	13	52	166	169	146	199	2.4*
Untreated control		26	18	35	127	522	265	142	199	3.6
LSD at $P = 0.05$										0.74

* Significantly different from the untreated at $P < 0.05$

NB—Analysis of variance carried out on data up to the 15th month

period are given in Table 11, the statistical analysis is based on the results up to the end of the first 13 months. Beyond this date, the treatments did not show clear differences from the untreated. The results show that the higher doses of all three insecticides gave significant reductions in shot-hole borer numbers, but there was no significant difference between these treatments. The analysis showed that there was no significant interaction between the treatments and the dates of sampling indicating that all treatments behaved in a similar manner at all dates of sampling. The repeat applications of the lower doses of heptachlor and dieldrin were not found to be very effective.

Experiment E35

In this experiment, three doses of heptachlor were evaluated against the untreated control. Although the experiment was conducted for a period of 19 months, results presented in Table 12 were analysed only up to the end of the first 15 months. The data obtained subsequently, indicated that none of the treatments were effective after 15 months (Table 12). Heptachlor at the rates of 1.7 lb (6 pints 23% EC) and 1.2 (4 pints 23% EC) gave significantly better control than heptachlor at 0.6 lb (2 pints 23% EC) per acre and the untreated control. There was no significant difference in the numbers of Shot-hole Borer found in the untreated plots and those treated with 0.6 lb heptachlor. The analysis also showed that all treatments showed no variations at different dates of sampling.

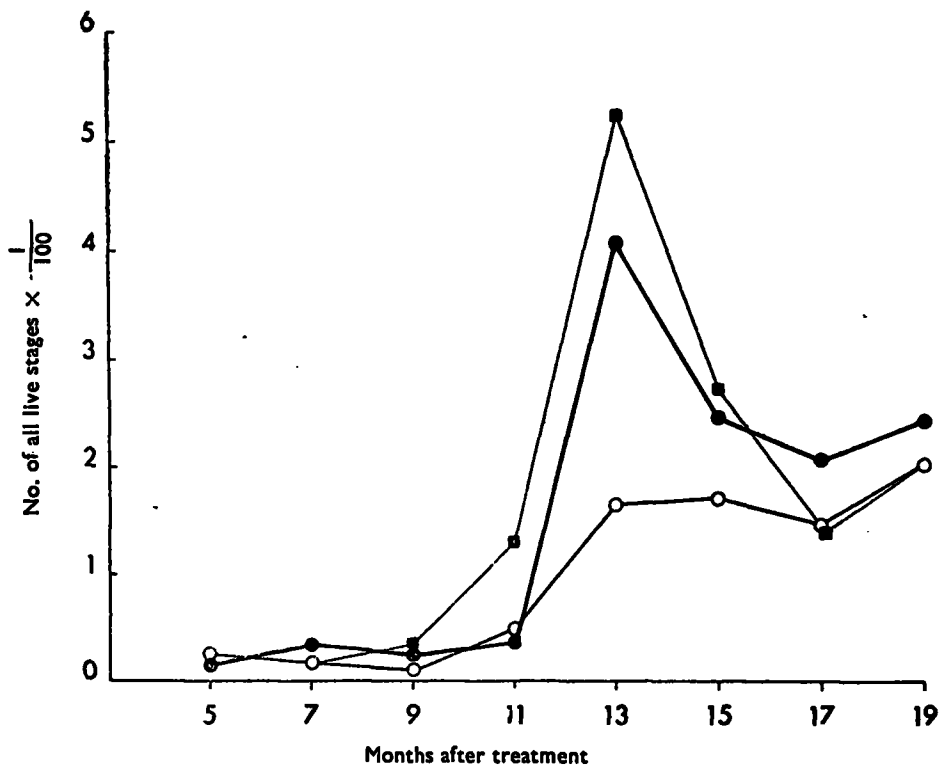


FIGURE 5 — Comparison of the degree of shot-hole borer control obtained with two doses of heptachlor

- — 1.7 lb heptachlor
- — 1.2 lb heptachlor
- — Untreated control

C—Effect of heptachlor on the parasite of Tea Tortrix *Macrocentrus homonae*

Experiment E19

This experiment was conducted in order to compare the effect of heptachlor on *M. homonae* with that of aldrin and dieldrin. The nature of this problem made it necessary that the plot size be larger than those of other experiments. The larger plots would tend to give better indications of side-effect problems. The experiment was laid out on randomized blocks with four replicates of four treatments (Table 13). The plot size was 1/4 acre and all plots were bordered by unsprayed tea so that plot to plot migrations of Tortrix and *M. homonae* were minimized. For each insecticide, 1.5 lb active material (6 pints 20 % EC) per acre in 50 gallons of water was used with knapsack sprayers. The first sampling was carried out at the end of three months after spraying and three more rounds of sampling were done at monthly intervals. Sampling was done by counting all caterpillars other than the first instar in 50 randomly selected bushes from each plot, so that in all, 200 bushes were sampled for each treatment on each occasion. The results are presented in Figure 6, where percentage parasitism of tortrix larvae by *M. homonae* are plotted against time. Parasitism was determined by dissecting the larvae collected from each treatment on each day of sampling. The total number of tortrix larvae found in each treatment on different occasions of sampling are given in Table 14. It must be noted, however, that at 3½ months after the spraying, the tortrix attack and damage became so severe that control measures had to be taken against Tortrix by spraying DDT (25% EC) at the rate of three pints per acre in ten gallons of water in mist-blowers. This spraying was done in all the plots, as well as in the rest of the field, in order to prevent the spread of Tortrix to other fields and neighbouring estates. It must be noted that DDT spraying does not have any adverse effects on the build up of populations of *M. homonae* (Danthanarayana & Ranaweera 1968). Table 14 shows that the highest number of tortrix larvae were found in the dieldrin-sprayed plots. The numbers of tortrix larvae found in aldrin and heptachlor treated plots and in the control plots were very similar and less than those found in the dieldrin-treated plots by 50%.

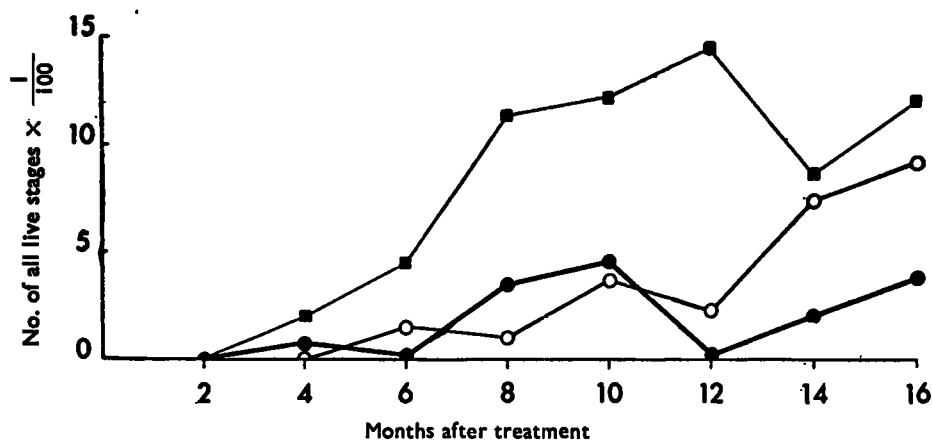


FIGURE 6— Comparison of the degree of shot-hole borer control obtained with heptachlor and endrin

- — 1.7 lb heptachlor
- — 1.2 lb endrin
- — Untreated control

The appearance of tortrix larvae in the untreated plots in such large numbers indicate that some movement of moths from the sprayed to the unsprayed plots had occurred (Figure 7). Of the three insecticides, heptachlor seems to have had the least effect on *M. homonae* (Figure 7) but the highest degree of parasitism occurred in the untreated plots. These results also show that parasitism of tortrix by *M. homonae* in the insecticide-treated plots were rather low during the first four months after spraying, but reached a higher level of over 80% by the end of six months.

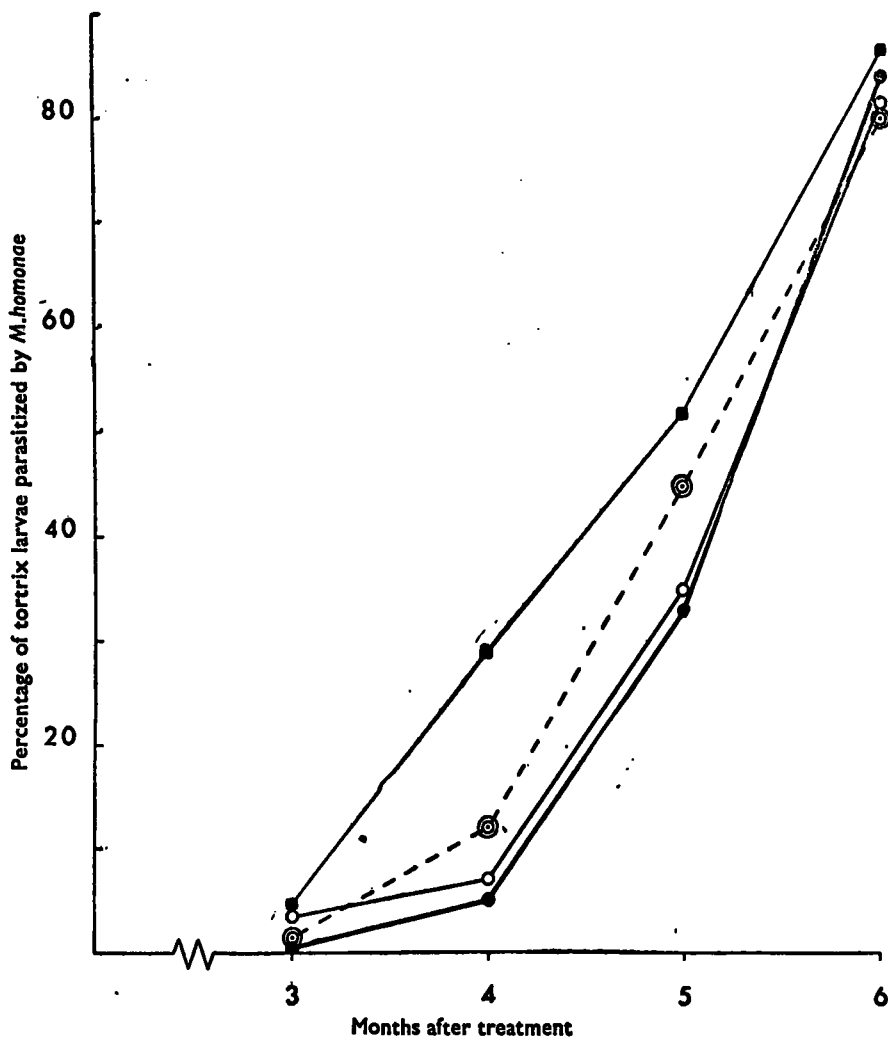


FIGURE 7 — Effect of insecticide applications on the parasitism of tortrix larvae by *M. homonae*—

- — 1.5 lb dieldrin
- — 1.5 lb aldrin
- ⊙ — 1.7 lb heptachlor
- — Untreated control

TABLE 13—*Post-treatment counts of live tea tortrix larvae in Experiment E19*

Treatment	Dose	No. of larvae per 50 bushes (months after treatment)			
	(lb ai per acre)	(3)*	(4)	(5)	(6)
Dieldrin	1.5	5185	525	484	245
Aldrin	1.5	2179	494	354	239
Heptachlor	1.7	2214	404	217	173
Untreated control		2525	444	168	122

* Sprayed DDT on all plots at 3½ months, at the rate of 3 pints (DDT 25% EC) per acre

Discussion and conclusions

In this series of experiments, altogether 26 insecticides, two fungicides and two insect pathogens were evaluated. The two insect pathogens, namely *B. bassiana* and *B. thuringiensis* did not show any adverse effects on shot-hole borer build up. Of the two fungicides, Bordeaux Mixture did not control the beetle to any degree, but nickel chloride gave slight reductions of borer numbers at higher population levels (E41). Overall results of nickel chloride, were not significant when compared with the untreated, and were inferior to those obtained with insecticides. The amount of nickel chloride used was rather high, but only a negligible degree of shot-hole borer control resulted. These results, however, did indicate that fungicides may be of some use in controlling the beetle by their effects on the ambrosia fungus, on which the beetle feeds.

Among the 26 insecticides evaluated, 18 belonged to the organophosphate group, six were of the organochlorine type and the other two were carbamates. The carbamate, arprocarb (Unden) showed no adverse effects on the Shot-hole Borer (E32) whereas methiocarb (Mesurol) indicated initial activity up to the end of the first month after treatment in one experiment (E41) and none on four others (E42 to E45). In an earlier series of experiments, two other carbamate insecticides, carbaryl (Sevin) and aminocarb (Metacil) have been evaluated by Cranham (1964; 1966a) with similar results.

Of the 18 organophosphate insecticides which included both systemic and contact-stomach types, significant results in controlling the beetle were given only by fenitrothion (Sumithion) (E41) and fenthion (Labaycid) (E44). In most of the experiments where these two insecticides were evaluated, the results clearly indicated that fairly good shot-hole borer control can be obtained for a period of about two months with a single application of 2.5 lb active material per acre. This affect was more clear in the case of fenitrothion. If satisfactory shot-hole borer control is to be maintained with either fenthion or fenitrothion, regular bimonthly applications will be required. Such regular applications will not be practicable after the first year from pruning because the insecticide cannot be sprayed satisfactorily onto the stems because of the dense foliage. Even with bimonthly applications, the degree of control obtained will be inferior to that which can be obtained with a single application of an insecticide such as heptachlor (Figure 1); and at the same time, the costs involved in bimonthly applications will be exorbitantly high (in the region of Rs 150 per acre per year or more). In addition to some of the organophosphate insecticides evaluated here, malathion, naled and parathion have been tested previously by Cranham (1964) with negative results.

Of the six organochlorine-type insecticides, heptachlor was evaluated in eight out of eleven experiments. Aldrin and dieldrin which are known to be very effective against Shot-hole Borer (Judenko *et al.* 1962; Cranham 1966b) were included as standard treatments, to compare them with heptachlor which gave good results in the first experiment (E28, Figure 1). The fumigant ethylene dibromide which was

tested twice did not prove to be effective. In all eight experiments where heptachlor was included as a treatment, the heptachlor-treated plots gave significantly lower counts of Shot-hole Borer than the untreated. Heptachlor at the rate of 1.7 to 2.3 lb (6 to 8 pints 23% EC) active material per acre gave results similar to that given by 1.5 lb (6 pints 20% EC) of dieldrin per acre (E28, E33, E34). When similar doses of heptachlor and aldrin were compared, heptachlor gave superior results (E33, Figure 3). Dieldrin appeared to be marginally superior to heptachlor in controlling the beetle, but this difference was not statistically significant in any of the experiments. The results clearly show that it is possible to obtain satisfactory shot-hole borer control for a period of up to 15 months, with a single application of 1.7 to 2.3 lb (6 to 8 pints 23% EC) heptachlor per acre (Figures 2 to 6). It was demonstrated that by annual applications of heptachlor at the rate of 1.7 lb per acre, a high standard of shot-hole borer control can be achieved in new clearings and the results were better than those which can be obtained with a single application of 1.5 lb aldrin or dieldrin (Figures 3 & 4). The results of experiments where different levels of heptachlor were compared (E28, E33 to E35) clearly showed that heptachlor performs better at the higher doses of 1.7 lb to 2.3 lb (6 to 8 pints of 23% EC) per acre (Figure 5). It must be noted that the formulation of heptachlor used in these experiments was a 23% EC formulation, but there are 20%, 25% and 40% EC formulations also available in Ceylon. Irrespective of the type of formulation, the amount of active material of heptachlor required for shot-hole borer control is between 1.5 and 2.0 lb per acre. This would mean that six to 8 pints of 20 to 25% EC or three to four pints of 40% EC may be used per acre.

Several other organochlorine insecticides have been tested previously by Cranham (1964; 1966a). These were: methoxychlor, Lindane (Gamma-Cereclor), isobenzan (Telodrin) and endosulphan (Thiodan). Of these only isobenzan has been shown to be effective against the beetle, but because of its high mammalian toxicity and severe tortrix side-effect, this compound was not recommended. The results of the experiment E19, where the tortrix side-effect of heptachlor was examined, showed that the numbers of tortrix larvae found after spraying heptachlor are considerably less than those which follow dieldrin spraying at the same dose. It was also clear that heptachlor is less harmful to the parasite *M. homonae* than either aldrin or dieldrin (Figure 7). Similar results have been obtained in six large-scale field trials carried out in different districts (Danthanarayana 1968). In these trials where heptachlor was tried out without interference from either aldrin or dieldrin, the tortrix side effect developed only in some instances, and the attacks were mild so that no control measures were necessary against Tortrix.

In the experiment (E46) where heptachlor was applied as heptachlor-treated absorbant paper, as a normal spray, and also in combination with the sticker 'Estab', all three types of application were equally effective. Heptachlor plus 'Estab' gave the lowest mean number of borers, but this was not statistically significant from the numbers found in the other two heptachlor treatments. Weathering gradually destroyed most of the heptachlor-treated paper in the respective plots; but these findings indicate that instead of paper, some other weather resistant material might be effectively used. Such a method of heptachlor application will be useful on low-country tea estates where the bush cover is often too heavy to obtain satisfactory spray deposit on the frames. A number of experiments are now in progress to investigate whether heptachlor-treated pieces of jute hessian will give equally good results.

The results of experiment E42 indicated that the insecticide endrin is capable of providing a high degree of borer control with a single application of 1.2 lb active material. Endrin appeared to be as good as, or better than heptachlor at 1.7 lb per acre, in controlling the beetle (Figure 6). Similarly, DDT at a high dose of 2.7 lb gave fairly good control up to a period of eight months. These results suggest that different doses of endrin and DDT must be examined in the future.

It is clear from this series of experiments that none of the insecticides in the wide range of organophosphate and carbamate compounds tested so far, have proved useful in controlling Shot-hole Borer. Any insecticide that can be used against the beetle must be highly persistent, and also effective. Both these properties to a greater or lesser extent have been shown only by aldrin, isobenzan, heptachlor, endrin, chlordane and DDT, which are all organochlorine insecticides. The control of Shot-hole Borer presents special problems because of the nature of the crop and the build-up of the attack. Tea bushes in infested areas are generally pruned every two or three years. The beetles usually attack only the young wood which has reached the size of about pencil thickness or more. When a bush is pruned, the branches supporting the beetle population are removed. New suitable wood for a fresh attack will appear only after eight months from the time of pruning and from then onwards the population increases up to about two years (Figure 2). To obtain a satisfactory degree of control, insecticides have to be sprayed on the frame, but if the bushes are older than about 12 to 15 months from pruning, it is not possible to obtain a good deposit of insecticides on the frames, as a result of the heavy cover of foliage. It is, therefore, necessary to spray insecticides before the bushes are older than one year from pruning. For this reason, in addition to being sufficiently effective the insecticides have to be persistent for at least a year. As pointed out earlier, the required efficiency and persistence have so far been clearly shown only by aldrin, dieldrin, isobenzan and heptachlor. The control given by fenitrothion and fenthion which lasts only for a maximum period of two months is, therefore, insufficient. It will also be pertinent to mention here that estates in shot-hole-borer affected areas are now run at considerable financial stress due to the fall in the sale price of tea. For economic reasons, many estates will not, therefore, be able to afford more than a single insecticidal application for shot-hole borer control each pruning cycle. When these factors and especially those of side-effects, are considered, it is clear that heptachlor is the most suitable insecticide at present, for controlling Shot-hole Borer.

Summary

- 1 — In 12 statistically laid out field experiments, 26 insecticides (18 organophosphate, two carbamate and six organochlorine) two insect pathogens and two fungicides were evaluated for shot-hole borer control.
- 2 — The two insect pathogens, *B. bassiana* and *B. thuringiensis* did not show any adverse effects on the build up of the shot-hole borer population.
- 3 — Of the fungicides, which were expected to have some effect on the ambrosia fungus, Bordeaux Mixture was not effective, but nickel chloride gave slight reductions of borer numbers only when the population of beetles was high. The results with nickel chloride were not significantly different from those of the untreated controls.
- 4 — The two carbamate insecticides were not effective against the beetle and out of the large number of organophosphate insecticides tested, only fenitrothion and fenthion gave significant borer control when applied at the rate of 2.5 lb active material per acre. The effect of a single application of either of these insecticides persisted only for two months. It was concluded that bimonthly applications are impracticable and uneconomical.
- 5 — It was clear that at present, only insecticides of the organochlorine group are capable of providing effective shot-hole borer control for a suitable length of time. In addition to aldrin and dieldrin, heptachlor too gave consistently good results. Endrin at the rate of 1.2 lb active

material per acre and DDT at 2.4 lb per acre were also effective, but these two insecticides need further investigation. Chlordane was effective at a very high dose of 2.8 lb per acre, but it gave inferior results when compared with heptachlor.

- 6 — Heptachlor emerged as a possible alternative to aldrin and dieldrin. Heptachlor at the rate of 1.7 to 2.3 lb active material per acre (6 to 8 pints 23% EC) gave borer control as good as 1.5 lb active dieldrin (6 pints 20% EC) per acre. Results given by heptachlor were superior to those of aldrin at similar rates of application.
- 7 — Duration of shot-hole borer control obtainable with a single application of six to eight pints of heptachlor (23% EC) was in the region of 15 months from the time of spraying. It was found that annual applications of heptachlor 23% EC at six pints per acre gave continuous borer control in new clearings.
- 8 — Of the three insecticides, aldrin, dieldrin and heptachlor, the latter showed the least tortrix side effect.
- 9 — When the efficiency, persistence, economics and side-effect problems were all taken into consideration, heptachlor appeared to be the best alternative to aldrin and dieldrin for shot-hole borer control.
- 10 — It was concluded that the most suitable time for heptachlor application is when a field is about one year to 15 months old from the time of pruning.

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References

- CRANHAM, J. E. (1961). The chemical control of Shot-hole Borer (*Xyleborus fornicatus* Eichh.) on tea. *Tea Q.* 32, 171-184.
- CRANHAM, J. E. (1964). Report of the Entomologist for 1953. *Rep. Tea Res. Inst. Ceylon* 1963 2, 74-90.
- CRANHAM, J. E. (1966a). Report of the Entomology Division for 1965. *Rep. Tea Res. Inst. Ceylon* 1965 2, 68-81.
- CRANHAM, J. E. (1966b). 'Mid-cycle' sprays of aldrin for the control of Shot-hole Borer. *Tea Q.* 36, 56-68.

- DANTHANARAYANA, W. (1966). Shot-hole borer control. *Tea Q.* 37, 100-105.
- DANTHANARAYANA, W. (1967). Ways to economize on insect and mite pest control. *Tea Q.* 38, 269-274.
- DANTHANARAYANA, W. (1968). Shot-hole borer control: recommendations 1968. *Tea Q.* 39, 115-118.
- DANTHANARAYANA, W. & RANAWEEERA, D. J. W. (1968). Chemical control of Tea Tortrix (*Homona coffearia* Nietner). *Tea Q.* 39, 50-60.
- GIBSON, A. L. (1957). Tests of bark-penetrating insecticides to control the Douglas-fir beetle. *J. econ. Ent.* 50, 266-268.
- JUDENKO, E. (1958). Trials with a method of assessment of infestation caused by Shot-hole Borer (*Xyleborus fornicatus* Eichh.) on old tea. *Tea Q.* 29, 51-59.
- JUDENKO, E., SHANMUGAM, C. & HASSELO, H. N. (1962). Field experiments on the chemical control of Shot-hole Borer (*Xyleborus fornicatus* Eichh.) on tea soon after pruning. *Tea Q.* 33, 69-87.
- VENKATARAMAIAH, G. H. & SEKHAR, P. S. (1964). Preliminary studies on the control of Shot-hole Borer (*Xylosandrus compactus* Eichhoff)—(*Xyleborus morstati* Hgdn.). *Indian Coff.* 28, 208-210.

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